

# **Large-scale cattle and pig production systems in three regions of Armenia: Engaging frontline persons in assessing the environmental, animal, & human health conditions of these systems**



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## **ABSTRACT**

This study is essential for the Republic of Armenia, as it provides an opportunity to investigate the economic and policy drivers, environmental impacts, and animal health and human wellbeing conditions of industry-scale pig and cattle production systems in Armenia. In this guidance memo, we describe the study region's demographic indicators and select animal welfare indices (land use, livestock status, and veterinary services), as well as specifics about the products and production processes considered in this study. Then, we discuss the current economic drivers of industrial-scale cattle and pig production systems in Armenia and some of the post-soviet regime changes that led to the collapse of some of the cattle and pig production systems and further unintended consequences. Current policies and incentive programs that influence these production systems are described. Finally, we describe the life cycle assessment (LCA)-based approach used to account for the potential environmental and human health impacts associated with the production systems, and report the findings from the LCA.

Part of this study includes the characterization of small-scale cattle and pig production systems so that we can discuss some of the differences of scale (industrial-scale and small-scale) in these production systems. In conclusion, this guidance memo identifies specific linkages or potential partnerships among industrial-scale cattle and pig production systems, small cattle and pig farmers, the Armenian government, and consumer groups. Each identified linkage will help to strategically reduce harmful animal, environmental, and human health impacts of industrial production while supporting sustainable practices and the economic viability of small- (and medium-) scale livestock farmers.

## **INTRODUCTION**

Through this study, we engage frontline persons<sup>1</sup> in an assessment of the environmental impacts, and human and animal health and economic conditions of large-, industrial-scale cattle and pig production systems in Armenia. We discuss post-soviet implications for the cattle and pig production systems, as well as current policies and incentive programs that influence them. Part of this work includes defining linkages and potential partnerships among industrial-scale cattle and pig production systems, small-scale pig and cattle production systems, government, and consumer groups to strategically reduce harmful impacts of industrial-scale pig and cattle production systems and to



Cattle farm of Hinnatavush, Tavush region

<sup>1</sup> Frontline persons in Armenia include individuals who work in organizations like “ISSD” Innovative Solutions for Sustainable Development of Communities” NGO, institutions like the Armenian National Agrarian University (ANAU), and small-scale farmers like a pig breeder in the Tavush region.

support more sustainable practices and the economic viability of small- (and medium-) scale pig and cattle production systems.

The research questions addressed through this work include: (a) What are the environmental, animal, and human health impacts of industrial-scale cattle and pig production systems in Armenia? (b) What are the economic drivers and policies that influence both large-scale and small-scale cattle and pig production systems in Armenia? (c) What role can frontline persons play in mitigating some of the negative impacts of industrial-scale cattle and pig production and in supporting sustainable practices and economic viability of small-scale farming systems?

### Defining the study systems

In Armenia, the main difference between cattle and pig production conventional farms, and cattle production and pig production industries (or complexes) is the volume of food/product produced by them, the mechanization/automation of those complexes, and the advanced labor and production organization (Davtyan, 2004). Industrial-scale systems in Armenia are large-scale systems per the Armenian classification system (defined in the **supplementary materials A**). The large-scale systems are different in scale compared to, for example, operations in the U.S. or Europe. For example, there is a fewer number of animals, a smaller extent of infrastructure, and less mechanization. From this point forward, we refer to the industrial-scale systems in Armenia as large-scale systems.

### Defining the study regions

Several regions in Armenia have large-scale and small-scale production systems. Given the duration of this study (initially four months, extended for two months due to COVID), we narrowed the scope of the work to include three of the main Armenian animal product production regions (aka marzes) (Aragatsotn, Kotayk, Tavush) (indicated in the map of Armenia to the right). Each area is described in terms of demographic indicators, select animal welfare indices, and the main cattle and pig production processes and products considered in this study.



### Demographic indicators

The human population density in the study marzes is 66 people per km<sup>2</sup> (Republic of Armenia Census, 2011). The most densely populated region is Kotayk (121 people per km<sup>2</sup>). This is explained by the urban communities in the area and the industrial importance of the region. In Aragatsotn and Tavush marzes, where the rural population is high, the population is not densely distributed. The study regions in total consist of 141,511 households. The permanent population is 499,291

people (48:52, men: women). The average age of the population in these regions is 36, and the community is gradually aging.

Overall, the birth rates in communities have reduced since 1994. This phenomenon is because of the collapse of the Soviet system and the emergence of the Nagorno-Karabakh conflict. These conditions led to the permanent or temporary emigration of young people and the lack of desire of young people to marry and have children because of poor living conditions.

In general, employment in the regions is high (93% in Aragatsotn, 75% in Kotayk and 70% in Tavush), but there is also a large number of job seekers and unemployed.

### **Livestock status in the study regions**

The agricultural sector has traditionally been a prominent part of the economy in the study regions. In general, agriculture production program incentives in the marzes are deployed according to physio-geographic conditions (e.g., land types, climate/suitability). The main agricultural production systems in the lower and middle zones of Armenia are vegetable growing, crop production, and fruit growing. In the highlands, the primary agricultural production is cattle breeding.

Brown Caucasian cattle breed predominates in all three marzes. Currently, many state and international projects are attempting to import high productive Schwitz, Simmental, Jersey breeds, as well as Angus breeds from abroad to raise dairy and meat products of the livestock available in Armenia. The total quantity of animals and products of animal origin was assessed for each region (**supplementary materials B**).

### **Select animal welfare indices**

The indices of animal welfare used for the study regions were selected based on the following rationale. Arable land is a critical indicator for determining the animal feed base, as both cattle and pigs are fed both concentrated feeds (barley, oats, corn), legume crops (alfalfa, clover, sainfoins), and other crops (beta, potatoes). Sufficient quantities of arable lands not only meet the demand of the local population for the production of foodstuffs and solving the food security problem, but are a precondition for a stable base of feed.

The second main point included regarding animal welfare is the status of veterinary services. The condition of veterinary services is essential to consider because the health of animals depends on the implementation of veterinary preventive measures. The leading cattle and pig production regions in Armenia included in this study are considered "epidemic," especially for land-borne infections. If veterinary preventive measures (e.g., vaccinations) are not implemented, the welfare indicators of animals will sharply deteriorate.

Indeed, other animal welfare indices could be considered that are not included within the scope of the current work (e.g., animal nutrition).

## Availability of arable land and grassland for animal feeding



Harvested hay in grasslands, Kotayk region

The total land area of Aragatsotn, Kotayk, and Tavush marzes is 754,584 ha, out of which the 483,608 ha (64%) are agricultural lands. Overall, the use of pastures, as well as pastures and grasslands belonging to forestland, is considered a cheap, practically free source of animal forage, which significantly reduces the overall cost of meat and milk production in these regions. The arable lands per household in Armenia is 3.4 ha, on average<sup>2</sup>. In contrast, in the study regions, there is about 1.0 ha of usable agricultural land, 0.3 ha of arable land, and 0.7 ha of natural pasture land is used per capita. Much of the land is shared or common pasture land and forestland.

## The State of Veterinary Services provisions in Aragatsotn, Kotayk and Tavush marzes

Veterinary service provision for animal diseases within the state order in the studied marzes is provided by the community veterinarian and anti-epidemiologists of the veterinary and phytosanitary services of the Republic of Armenia Aragatsotn, Kotayk, and Tavush State Non-Commercial Organizations. Typically, veterinarians work on a contractual basis. The remuneration is made based on the number of vaccinations carried out and is an estimated 80 Armenian Dram (approximately 0.17 USD) per 1 conventional livestock per 2019/2020 calculations.

Preventive measures are implemented in the framework of the state order against the following animal diseases: brucellosis of cattle and small bovine animals, foot-and-mouth disease, anthrax, bradzot of small bovine animals, tuberculosis of cattle, pasteurosis of cattle, blackleg, classical swine plague, newcastle disease in poultry, and bee varroa destructor<sup>3</sup>. In general, there is an increased risk of contagious livestock in the study marzes, in particular, for foot-and-mouth disease and anthrax. However, vaccinations are available and can decrease the risk of these infectious animal diseases if provided.

## Production processes and products

This study investigates cattle and pig production systems and products. In this section, the production systems are assessed in terms of current practices. The following production system descriptions are based on the data collected for this study.

<sup>2</sup> Operational Program for Territorial Development of the Republic of Armenia 2018-2020  
<http://www.mtad.am/files/docs/2049.pdf>

<sup>3</sup> [https://www.e-gov.am/u\\_files/file/decrees/kar/2012/02/12\\_0206.pdf](https://www.e-gov.am/u_files/file/decrees/kar/2012/02/12_0206.pdf)

## Cattle Production Processes: Meat, Milk, and Cheese

Typically, cattle are grazed in the grasslands. During the winter months, they may be fed mixed feed comprised of bran, barley, and corn. Alfalfa is often grown to supplement the amount of food for cows in the winter months (October through April). After castrating the cattle, they are fattened and then slaughtered. For cows whose milk quality has decreased, the farmers dry, fatten and slaughter them.

The farmers will carry different numbers of animals, producing different amounts of meat each year based on several factors. These factors include the length of the drought period and the amount of accumulated feed and, thus, the number of cows/calves. The bulls are slaughtered immediately after fattening during the grazing period, whereas the cows are killed when they are old, and the amount of milk decreases.

In general, cows are milked twice a day, morning and night. Larger scale production systems used mechanical milking machines. The amount of milk produced varies depending on the year (e.g., if there is a drought or not). If the farmers return from the mountains early, cows' milk production typically decreases. This year (i.e., in 2020), it's the second year of a drought in the mountains, and the grass is drying up quickly. Also, the amount of milk produced depends on the milk recipient. If the milk factory is small or the farmer cannot provide a lot of cheese, the cows have to be dried and slaughtered. There have been several such cases and very risky.

Overall, there is a wide range of potential products milk processors can produce like sour cream, cottage cheese, and cheese. These products are mainly sold in the local and city markets. In most cases, the amount of milk the milk processors collect does not match the supply from the farmers, and the farmers will make cheese with the extra milk they have available at home. Cheese is often produced in the winter months.

It is essential to note the main milk products produced in the study regions are unique to the Armenian way of life and culture, namely a feta-like, a bit brittle, salty cheese (called Chanakh), and a softer texture, white-yellow cheese (called Lori). One other typical brine cheese is Chechil, produced in the Armenian Highlands. These three typical Armenian kinds of cheese are inexpensive compared to imported cheeses. For example, the gouda-like white-yellow cheese sells for ~3 USD per kg compared to Dutch cheese (~15 USD per kg) and imported smoked cheese (~25 USD per kg).

## Pig Production Processes

In some regions such as the Tavush region, pigs go to the forest from spring to late autumn and mostly eat and pasture in the forest. Sometimes they don't even



Water reservoirs, Aragatsotn region

return home during the nights. In other regions, pigs roam in the village area or household farm area.



Pig containment area, Aragatsotn region

Pigs are considered omnivorous animals. They eat almost all types of fruits, vegetables, sweet roots, tubers, small animals, and worms. During the winter months, they may be fed mixed feed comprised of barley and broken corn. In the summer season, pigs drink water from forest springs. When they are in the villages, pigs use the water tank installed in a yard or common area, where water is poured from the internal drinking water network. Often the water is held in a tire, horizontally cut into two parts, which is filled with water or used to feed the pigs.

Pigs are fed all year round, fattened, and slaughtered during the winter months. Many pigs are slaughtered before the New Year holidays. During the New Year holidays, the pig leg is the main dish (a delicacy). Also, in December, the pigs are well fattened (because of the forest feed), so they are heavier. Only the mother sow and piglets born within the respective year will be kept in the winter months.

### Meat Products

In 2018, 49,000 tons of live animals (combined pigs, cattle, poultry) were slaughtered in the study marzes. With a dressed weight (or deadweight) of 45%, we calculated approximately 22,050 tons of meat. In winter months, the price of meat is about ~2,800 AMD (or ~5.83 USD) per 1 kg of pork and ~3,100 AMD (or ~6.46 USD) per 1 kg of beef. In the summertime, the price for meat decreases to ~2,300 AMD (or ~4.79 USD) per 1 kg of pork and ~2,750 AMD (or ~5.73 USD) for 1 kg for beef.

### Dairy Products

In 2018, around 190,000 tons of milk were produced in the study marzes. In winter months, the price of milk is ~350 AMD (~0.73 USD) per 1 kg. In the summertime, the price for milk decreases to ~130 AMD (~0.27 USD) per 1 kg. Overall, there are many collection centers (one for every 2–3 village). The number of production facilities in the region is 3–4 in total.

### Overall Economic Status of Production in Each Region (or Marz)

In each region, two main trends observed in 2019 compared to 2018 include (1) decreases in cattle production and (2) increases in pig production. The exception is in the Tavush region, where there is a slight increase in cattle production. Overall, the cattle production decreases are likely due to the 2018 revolution in Armenia and because people have ceased to engage in agricultural activities that are more labor-intensive. The pig production increase is expected due to the increased demand for pork meat and the relatively low cost of pork production.

## **Aragatsotn marz**

Livestock farming is a stable production system in Aragatsotn marz's economy, making up approximately 56% of the region's total agricultural production. In this region, livestock farming is mainly developed in the mountainous settlements (Aparan, Aragats, and Talin communities). Pastures (60%) and arable lands (25%) have the highest share of agricultural land.

In this region, the number of cattle in 2019 (67,815 head) compared to 2018 (68,293 head) decreased by 1%. In contrast, the number of pigs increased by 47% in 2019 (17,896 head) compared to 2018 (12,199 head). It's useful to note that the Aragatsotn region is one of the leading suppliers of meat to nearby cities (i.e., Yerevan).



Milk collection, Aragatsotn region

## **Kotayk marz**

Horticulture and cattle production plays an essential role in the economy of the Kotayk marz. Currently, the farming households organize and manage the agricultural production systems. Overall, there are more than 15 specialized companies for the processing of animal products, the demand for which is quite high in Armenia's market.

The number of cattle in 2019 (52,844 head) compared to 2018 (54,143 head) decreased by 2%. In contrast, the number of pigs increased by 7% in 2019 (24,102 head) compared to 2018 (22,420 head).

## **Tavush marz**

Tavush marz is one of the leading agricultural regions of Armenia. According to natural conditions, which somehow defines agricultural specialization, the marz is divided into two sub-zones: the lowland region, which is deforested and is mainly oriented in vegetable- and fruit-bearing, and the mountainous region, which is forested and livestock-oriented. Pig breeding/production systems are 72% of the gross domestic product in this region (i.e., Tavush region).

The number of cattle increased in this region by 2% in 2019 (30,207 head) compared to 2018 (29,644 head). This increase is due to the early onset of the spring in 2018/19 and the availability of herbage in the area. Similarly, the number of pigs increased (by 6%) in 2019 (17,725 head) compared to 2018 (16,675 head).

## **Post-Soviet government & large-, industrial-scale cattle and pig production systems in Armenia**

After the collapse of the Soviet system and the privatization of land, when the peasantry no longer operated based on the dictated scientifically-based agricultural principles, land conditions deteriorated. In general, the decline in operations with the livestock production systems disrupted the rotational connection between pastoralism and arable farming. In contrast, in the lands

adjacent to livestock supporters, connected with the accumulation of animals, the quantity of nitrate and nitrite increased. As a consequence, the food crops grown there were contaminated, causing human and animal poisoning and illness. Recent studies also show that the animals raised in these regions have an expressed deficiency of minerals that can lead to diseases in humans and animals, such as tuberculosis (Harutyunyan, 2018).

Also, the interconnection between arable farming and pastoralism, as well as the food chain, was disrupted. The arable lands were deserted. In effect, there was an insufficient amount of grains produced, resulting in a decrease in farm animals. In other words, there was a food and forage shortage.

Currently, there is a "return" to these lands. The farmers have an incentive to work in the area. Instead of leaving them as grasslands, the farmers can receive financial benefits for the sale of the products they can produce in these regions. For hay, farmers receive a net income of ~10,000–15,000 thousand Drams (~20.83–31.24 USD) per year per hectare. For crops like barley, farmers have the opportunity to receive ~380,000 Drams (~791 USD) per year per hectare and ~2,600,00 Drams (~5,415 USD) per year per hectare for potato or grape cultivation, depending on the variety of potato and grape.

### **Current policies and incentive programs that influence cattle and pig production systems in Armenia**

#### **Resources – Water and Electricity**

In border villages, both water and electricity are subsidized or free. These incentives are incredibly impactful in regions like the Tavush region. In the Tavush region, some communities (in the worst position due to their proximity to Azerbaijan) are not required to pay taxes. The water is often not metered and therefore is free. Also, in the same villages that are located in the worst positions (near the border), the farmers and other occupants of those villages have subsidized electricity. For example, they received solar panels to meet their energy needs and/or they may receive up to 50% discount the cost of electricity per kWh (up to 1440 kWh)<sup>4</sup>. Because the farmers in these villages do not have to pay as much for the water and electricity inputs to the cattle and pig production systems, they can offer their products at a lower price to the processor or consumer (compared to other production villages in the Tavush region and other regions).



Binas – where the farmers live

#### **Animal Wellbeing**

In 2014, the Republic of Armenia approved the Law on Veterinary services<sup>5</sup>. It regulates the relations related to the implementation and management of the

<sup>4</sup> <http://www.irtek.am/views/act.aspx?aid=78561>

<sup>5</sup> <https://www.arlis.am/DocumentView.aspx?docID=101830>

veterinary services. It applies to all entities involved in the veterinary roles, including those individuals involved in the field of veterinary sciences. This law generally defines provisions of animal welfare. For example, animals must be bred and kept following their growth, physiological needs, and species characteristics (section 10, article 31)<sup>5</sup>. Depending on the species, age, and breed of the animal, the following provisions must be provided: (1) sufficient food and water, (2) free access to eating and drinking areas, and (3) appropriate eating and drinking accessories that are customized to stop their pollution and to reduce the aggressive competition between animals (section 10, article 31)<sup>5</sup>. Also, each animal must have the appropriate microclimate of life, prevention and treatment of infectious and non-communicable diseases, and care for illness or injury (section 10, article 31)<sup>5</sup>.



Shepherds keeping the animals in the mountains during the summer period

Currently, the draft law of the Republic of Armenia "On Responsible behavior for Animal Care" is in review with the National Assembly<sup>6</sup>. If the draft is approved, the law will regulate the basic principles of legal regulation in the field of animal treatment (i.e., humane treatment towards animals, which is a criterion of animal and human wellbeing within the framework of universal ethical values, etc.).

Also, several local and international programs have implemented livestock development programs. Recently, the Government of the Republic of Armenia approved the support of the Centre for Agribusiness and Rural Development (CARD) Foundation in partnership with Heifer Georgia International. Together, these groups initiated a project referred to as the "Animal Health Management in Cross-Border Areas of Armenia and Georgia," financed by Austrian Development Cooperation. In concept, the project will ultimately benefit the rural population in four regions of Armenia and Georgia: Shirak and Lori in Armenia and Kvemo-Kartli and Samtskhe-Javakheti in Georgia.

Overall, this project aims to improve best practices in animal husbandry and health control to provide better conditions for their economic activities. The project focuses on shifting from traditional farming to new animal husbandry approaches such as (a) herd and labor management, (b) reproduction, (c) housing and environment, (d) nutrition, (e) calf rearing, (f) trans-boundary animal diseases prevention and control, and (g) development of a more diversified rural economy<sup>7</sup>.

The project will also introduce and launch a system of universal cattle numbering and registration in the country. The following information will be included in each registration cattle number: location, movement, sex, race, and mandatory veterinary measures. Animals will be numbered using an ear tag with

<sup>6</sup> <http://www.parliament.am/drafts.php?sel=showdraft&DraftID=8061&Reading=0>

<sup>7</sup> <http://card.am/hy/categories/1/projects/9>

an electronic chip. The ear tag will contain information about the specific number of the animal within Armenia. The complete details on the animal will be available through the rapid response code (referred to as the Q.R. code) on the ear tags and the radio frequency label (i.e., the radio frequency identification system or RFID). Also, the CARD Foundation, with the financial support of FAO, carries out the mapping of Armenia's and Georgian dairy value chain by identifying development issues in the sector.

Many livestock development programs have been implemented with funding from the Austrian Development Agency. The "Livestock Development in the South" and "Livestock Development in the North of Armenia" programs were implemented, which aim to improve pastures, develop legume crop cultivation, promote artificial insemination, create milk processing opportunities, and upgrade cattle breeding in Armenia<sup>8,9,10</sup>. These projects were implemented through the Armenian-based "Strategic Development Agency" NGO.

### Breeding Programs

The CARD Foundation, with the financial support of various grant organizations, also carries out artificial insemination of cattle and pigs in the Republic of Armenia, the aim of which is to increase the productivity of animals through sorting. The price of artificial insemination of pigs, depending on the semen, fluctuates between 5,000–10,000 DRAMS (10.41–20.83 USD). The cost of artificial insemination of cattle is in the range of 10,000–15,000 DRAMS (20.83–31.24 USD).



Another view of binas (temporary shelters), Tavush region

Different companies, such as "Smart Agro," organize training on pig genetics and nutrition for the individuals and organizations involved in pig breeding and agricultural animals feed sales. The goal of this effort is to develop the pig industry in Armenia<sup>11</sup>. To be eligible for a training (or an award), a farmer must send a letter of request, verify their ownership or rental agreement for their operation, and describe their

agricultural system (e.g., number of animals, area of land).

In a different program referred to as the Government of the Republic of Armenia Cattle Breeding System 2019–2024 program<sup>12</sup>, the government aims to supply livestock breeders in Armenia with highly productive cattle by subsidizing the loan interest rate. It will enable replenishing herds with high productive

<sup>8</sup> <https://www.entwicklung.at/en/ada/news/detail-en/proper-pasture-management-from-seed-to-harvest>

<sup>9</sup> <https://www.entwicklung.at/en/projects/detail-en/livestock-development-in-armenia-south-north-oeza>

<sup>10</sup> <https://www.entwicklung.at/en/projects/detail-en/livestock-development-in-armenia-south-north-deza>

<sup>11</sup> <http://card.am/en/news/170>

<sup>12</sup> <https://mineconomy.am/page/1341>

livestock instead of the animals of unknown ancestry, and low productivity or reproduction difficulties. Also, the program will further develop the pedigree work, improving the productivity of domestic animals through interbreeding methods. The overall objective of the program is to increase the volume of meat and milk production and reduce the total costs (price) of meat, thus making it more competitive with similar imports.

### **Recent Coronavirus-related Programs**

State support for the construction and reconstruction of small and medium-sized "smart" farms and their technical maintenance program: Under the provisions of this program, grants are provided to farmers for the construction and operation of livestock facilities for animals. The program started at the beginning of 2020. There are no results yet.

This program works on the principle of crediting (loans). To obtain state support, farmers must submit relevant organizational and legal documents to the government, after which they can apply to banks for low-interest loans. According to this program, the state co-finances up to 75% of small- and medium-sized businesses to build a "smart" livestock building, which is equipped with normal animal behavior and welfare conditions. The program aims to improve the food characteristics of the animals by promoting their welfare<sup>13</sup>. For example, the state gives certain subsidies to small- and medium-sized enterprises to build stationary and mobile slaughterhouses to develop the slaughterhouse business<sup>14,17</sup>. To ensure food quality, the Food Safety Inspectorate will closely monitor this program<sup>15</sup>.

### **Environmental impacts of large-scale cattle and pig production systems in three regions of Armenia**

In this study, we used a lifecycle-based approach to account for the environmental and human health impacts associated with the large-scale and small-scale cattle and pig production systems in Armenia.

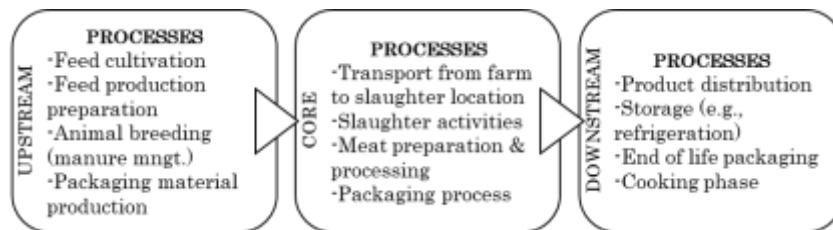


Figure 1. Generalized system diagram for the meat of mammals (cow and pig) illustrating main processes in the upstream, core, and downstream processes (UN CPC 2111, 2012).

For the system boundary and modeling used to assess the environmental impacts of these systems using the LCA approach are per the most recent

<sup>13</sup> <http://www.irtek.am/views/act.aspx?aid=99082>

<sup>14</sup> <https://smednc.am/hy/inner/553>

<sup>15</sup> Republic of Armenia, Requirements for slaughterhouses. <http://snund.am/>

Environmental Product Declaration and Product Category Rules for Meat of Mammals (UN CPC 2111, 2012). In the current study, we include the upstream and core processes. The downstream processes are excluded because they are beyond the scope of the study. Our research focuses on on-farm production systems. Currently, the slaughtering of animals is co-located near the production system. In every recorded case included in this study, the primary product(s) (e.g., meat) are not packaged when delivered or picked-up for further processing at the meat facility/retail store.

The system boundary and modeling for the milk production systems are per the most recent Environmental Product Declaration and Product Category Rules for Raw Milk (UN CPC 022, 2013). In the current study, we include upstream and core processes. We describe the transport to customers/consumers, but the other downstream processes are not included within the scope of the study.

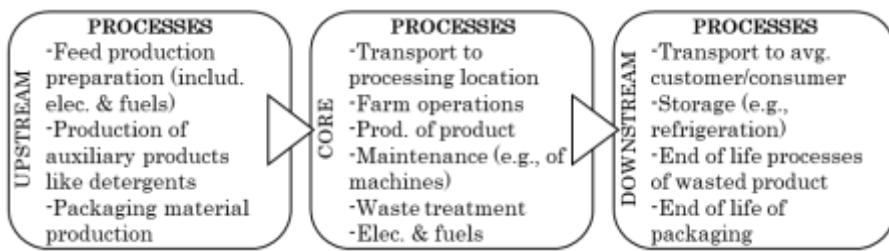


Figure 2. Generalized system diagram for milk illustrating main processes in the upstream, core, and downstream processes (UN CPC 022, 2013).

Data for the study were collected through surveys. Initially, we conducted two pilot surveys to evaluate the effectiveness of the survey and interview format (semi-structured interviews conducted by way of the telephone). We used this initial evaluation to revise the survey content as needed. **Supplementary materials C & D** provides more details about the data collection and processing.

### Critical Impacts: Results based on data analysis and LCA

The top impacts (i.e., the hotspots) from the LCA study are included in the following section. In this report, we mention the top two impacts of the LCA study. The top impact of the large-scale cattle production systems is the use of diesel. The use of diesel resulted in GHG emissions (e.g., 1.32–2.64 CO<sub>2</sub>e/kg cattle meat produced). The top environmental impacts associated with the small- and large-scale cattle and pig production systems is the burning of plastics. The burning of plastics poses human and environmental health issues (e.g., due to the release of dioxins, heavy metals, and particulates). For humans, these emissions can lead to respiratory ailments, among other potential health problems.

Also, we indicate the top two environmental effects that are not LCA-based results; however, they are based on the survey data collected and data analysis completed for this study. For large-scale cattle and pig production systems, these impacts include (1) wastewater run-off into nearby waterways, and (2) the

accumulation of manure and associated consequences (e.g., methane emissions from the manure and collection of nitrates in fields that can leach into the groundwater). The mass of manure is more of an issue for cattle production than pig production. However, manure management is a critical issue for both production systems. The wastewater contains solid and liquid waste from the sheds or other containment areas (for cattle and pigs). This liquid waste also includes soap water from the milking room or milking equipment, and other non-point source pollutants from the cattle and pig production systems run into nearby water bodies (e.g., rivers).

In this guidance memo, we broadly define each of these critical findings. The full LCA-based results and more on each of the critical impacts indicated in this guidance memo are further addressed in the related peer-reviewed publication (Winans and Mkrtchyan, in preparation).

### **Key differences between large-scale and small-scale cattle and pig production systems**

As mentioned earlier in this document, the difference between cattle and pig production systems that are smaller and more conventional and those that are industrial (or complexes) is the volume of food/product produced by them, the mechanization/automation of those complexes, and the advanced labor and production organization. For the regions included in the study, we clarify what this means in terms of the differences between large-scale and small-scale cattle and pig production systems.

#### **Cattle production systems**

In some cases, large-scale cattle production systems use stables year-round. In this case, the cows are fed purchased grass and do not graze in the nearby fields. The cows rotate between the cowshed, the cow yard, and the milking room (if milking cows). In general, in these conditions, there is an increase in the milk production (from 15kg/cow to 19 kg/cow) and meat production (from 200 kg/cow to 225 kg/cow).

The total inputs to the system (e.g., electricity and diesel fuel) are higher in large-scale production systems (as quantified above). Many of the other conditions are similar between small- and large-scale production systems (e.g., the milking is done mechanically, and the water comes from nearby natural sources/networks and is free). In both small- and large-scale production systems, the primary products (milk, meat) are not packaged. Instead, they are sold directly to the processor or market as bulk items (as milk in metal buckets and whole, skinned animals). In terms of labor, many of the large-scale systems require hired labor. In addition to the family members (i.e., the parents, children, and grandparents), 5 to 7 employees are hired to work the farm. In some cases, all labor are employees (i.e., no family members operate the farm), but this scenario is less common.

## Pig production systems

In general, large-scale and small-scale pig production systems are similar. These systems have similar practices with low inputs in terms of materials, fuels, feed, and energy—per pig. Also, both large- and small-scale farmers co-operate with local cattle farmers (e.g., to collect whey to feed their pigs). In terms of labor, many of the large-scale systems require hired labor. In addition to the family members (i.e., parents, children, and grandparents), up to 5 employees are hired to work the farm.

## Conclusions

In this section, we highlight specific linkages and proposed partnerships among large-scale cattle and pig production systems, small-scale cattle and pig farmers, the Armenian government, and consumer groups.

### Information exchange

The first recommendation is to promote information exchange between producers and consumers about production systems and product-level impacts. Potential linkages that would influence production systems and product-level has implications for the producers, the consumers, and the sanitary and food safety norms associated with animal health and wellbeing.

For example, we need the programs that aim to improve the food characteristics of the animals by promoting their welfare and simultaneously aide regional producers in their economic stability (e.g., state support of small- and medium-sized businesses to build a "smart" livestock building and mobile slaughterhouses).



Manure-covered area were cows spent the night (outside), Tavush region

### Government programs and incentives

The second recommendation is for frontline persons and government agencies to collaborate in developing education and awareness programs and adequate incentives for best practice in the management of manure and waste materials like plastics.

Examples of these efforts include the process of recycling manure and kitchen household waste. For example, the Green Agriculture Initiative is setting up a manure composting facility. Also, the CENN-funded Green lane NGO is setting up a composting mini-factory (in Tavush). However, none of these entities are currently operating. There are several recycling facilities for plastic waste that accept PET, HDPE, P.P., and LDPE types of plastic. The plastic recycling industry is generally organized in Yerevan, but there are some facilities in other regions (including Kotayk).

### Watershed education

Based on this work, the last recommendation is for frontline persons to work on monitoring the water activities at the watershed scale. These efforts would

include monitoring water quality both upstream (near the spring(s) or watershed head) and downstream (at different points/villages along the waterway/river(s) to help identify (1) fluctuations in water quality over time, and (2) sources of water pollution. These efforts should be paralleled discussions between stakeholders within the watershed about water use and water quality in a basin. Such educational programs could be partnered with concurrent efforts to establish information exchange and linkages between producers and consumers about production systems and product-level impacts.

The agricultural university extension services, if reinstated, could support such programs (i.e., as they had done in the past when these programs existed). For example, the USDA implemented the USDA Marketing assistance program in Armenia. The Extension system was created within the Agrarian University. Based on Extension Agriculture Support Centers were established in all regions, which, together with the University's Extension Department, have implemented numerous educational, consulting, and research programs, trying to develop the knowledge of farmers/producers. The aim was to help the farmer make decisions on their own and improve the economy. Within the framework of the Extension system, numerous advisory booklets and leaflets were published for farmers, thousands of seminars were conducted on how to carry out agricultural activities properly, without harming nature, animals or people.

Another conclusion of the work is the importance of forming linkages between frontline persons, producers, consumers, and government officials that address waste materials (manure and plastic) within the production systems and villages, and wastewater treatment within the watersheds. Again, it is likely that the government will need to support frontline persons in their efforts to address these efforts. For example, a government incentive program may be able to encourage natural wastewater treatment systems that generate additional revenue for the producer(s).

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## **SUPPLEMENTARY MATERIALS**

### **Supplementary Materials A**

The Armenian size classification system per animal group are indicated below in the text.

Note: Cattle and pig as well as chicken, sheep, and goat populations are stated here because many of the pig and cattle production systems are mixed systems (i.e., they include pig, cattle, sheep, goat, and chicken).

#### Pigs

Large - 51 and more

Medium - 31-50

Small - 11-30

Extra Small - up to 10

#### Sheep

Large - 201 and more

Medium - 101-200

Small - 21-100

Extra Small - up to 20

#### Cattle

Large - 101 and more

Medium - 51-100

Small 21-50

Extra Small up to 20

#### Goats

Large - 201 and more

Medium - 101-200

Small - 21-100

Extra Small - up to 20

#### Poultry

Large - 2001 and more

Medium - 501-2000

Small - 71-500

Extra Small - up to 70

## Supplementary Materials B

Table. Number of livestock in the marzes under study, 2019

Animals	<u>Number of Livestock, Total, Head</u>						
	Aragatsotn	compared to the past year, %		Kotayk	compared to the past year, %		Tavush
Cattle	67,815	99	52,844	98	30,207	102	
<i>of which: cow</i>	33,160	100	23,551	98	13,286	98	
Pig	17,896	147	24,102	107	17,725	106	
<i>of which: sow</i>	4,016	145	3,545	106	2,726	117	
Sheep	76,034	101	36,229	91	12,297	92	
<i>of which: ewe</i>	60,441	106	29,620	98	7,967	95	
Goat	2,879	105	2,210	86	1,929	111	
<i>of which: mother goat</i>	2,257	115	1,717	85	1,394	122	
Hors	295	108	602	96	2,420	125	
Poultry, total	416,816	75	731,945	94	185,934	96	
<i>of which: laying hen</i>	346,298	93	528,421	108	131,945	96	
Conditional livestock <sup>1</sup>	89,706		79,159		43,086		
Conditional livestock per capita	<1		<1		<1		
Conditional livestock feed per household	2		1		1		

Note: Cattle and pig as well as chicken, sheep, and goat populations are indicated in Table 1 because many of the pig and cattle production systems are mixed systems (i.e., they include pig, cattle, sheep, goat, and chicken).

<sup>1</sup>Conditional livestock refers to an agricultural economics concept that allows all animals to be conditionally converted into one large cattle to ease economic calculations. Ref.: [www.armstat.a](http://www.armstat.a)

## **Supplementary Materials C**

### **Data collection and processing**

The total population and producer population per respective system (cow or pig) were accounted for to calculate a statistically representative sample within each region. Also, the representative sample size represents the producer population for the respective size class of production operations (i.e., extra small-, small-, medium-, and large-scale systems) (**see supplementary materials D**).

The surveys were administered through a series of phone interviews for the representative populations and regions. These surveys were carried out over approximately two months. The data were then processed using Microsoft (M.S.) Excel. Basic observational statistics were conducted using M.S. Excel functions. The final data tables for the life cycle assessment (LCA) models, also developed in M.S. Excel.

## Supplementary Materials D

Table. Sample size representative of the producer population for the respective size class of production operations<sup>1</sup>

REGION	CATTLE		Total no. of surveys conducted per rep. sample		PIG		Total no. of surveys conducted per rep. sample	
	X Sm. -Sm.	Med. -Lg.	X Sm. -Sm.	Med. -Lg.	X Sm. -Sm.	Med. -Lg.	X-Sm. -Sm.	Med.- Lg.
<b>TAVUSH</b>	pop size	6,428	34	11	7	6,947	6	1
	est. rep sample (10%me <sup>2</sup> )	84	25			65	4	
	Est. rep sample (30%me)	10	8			8	2	
	Est. rep sample (50%me)	4	4			3	2	
<b>KOTAYK</b>	pop size	9,696	102	4	4	2,230	27	3
	est. rep sample (10%me)	85	47			64	20	
	Est. rep sample (30%me)	10	9			8	6	
	Est. rep sample (50%me)	4	4			3	3	
<b>ARAGATSOTN</b>	pop size	12,920	82	1	3	3,489	5	2
	est. rep sample (10%me)	7	7			7	4	
	Est. rep sample (30%me)	2	2			2	2	
	Est. rep sample (50%me)	2	2			2	2	

Confidence level: 99%. <sup>1</sup>See the Armenian size classification system per animal group in the supplementary materials A. <sup>2</sup>%me refers to percent mean error.

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